Guest Editor's Introduction

Dr. John L. Bailey

The theme of this issue—"Future Surface Combatants: Engineering the 21st Century Navy"—is particularly relevant at a time when design of the DD 21 class, LPD 17, and of CVN 77 and its successors is underway. These ships will almost certainly differ significantly from their predecessors; they will form the backbone of the U.S. Navy for at least the first half of the 21st century. The articles in this issue describe some of the systems these ships may carry and methodology that will be key to efficiently engineering them. The Dahlgren and Panama City laboratories have been important contributors to the Navy for many years. This issue describes some of the contributions we continue to make—contributions that are, in many aspects, quite different from those of the past.

> The best Ambassador is a Man-O-War.
> —*Oliver Cromwell*

Early Surface Combatants

In this issue we will see how evolving technology is affecting ship design and engineering. In this last year of the decade, century, and millennium (as popularly understood), it is appropriate to first consider its effect in the past. Since the dawn of sailing, the availability of technology has defined the way ships, particularly warships, are designed. Propulsion consisted of oars and wind until the 1800s. Technology gradually enabled shipbuilders to improve the capability and performance of these ships, principally by installing larger and more efficient sails. Near the height of that era, Nelson's flagship, *HMS Victory*, displaced 3500 tons and could hoist four acres of sail, which is approximately equal to the deck area of a modern aircraft carrier. The evolution of propulsion accelerated as steam gradually replaced sail, and again as oil replaced coal as the fuel of choice.

Until the introduction of naval guns midway through this millennium, the fundamental means of fighting ships had changed little from ancient times. Bows and arrows, spears, catapult, ramming, and hand-to-hand fighting were the primary combat systems. Smooth bore cannons in increasing numbers (100 on *HMS Victory*) on increasingly larger wooden ships dominated naval warfare until the mid-1800s. Boarding, involving musketry and hand-to-hand fighting, still settled many battles. The introduction of rifled naval guns (a project of our namesake, Rear Admiral Dahlgren), turrets, and armor during the 19th century gradually made naval battles a longer-range proposition. By the end of the 19th century, the evolution of combat system design was accelerating.

THE 20TH CENTURY SURFACE COMBATANT

One hundred years ago, a revolutionary surface combatant was being designed. The first ship of this class was *HMS Dreadnought*. Promoted by Britain's greatest admiral since Nelson, First Sea Lord John Fisher, *Dreadnought*-class ships were the world's first all big-gun battleships. Each carried ten 12-in guns (later ships of the class had 13.5- and 15-in guns). Predecessors typically carried four big guns and many smaller ones. The first battleship with turbine engines, the *Dreadnought* was faster (21 knots) than previous classes and heavily armored. Centralized fire control was first introduced on this class of ships. It was also the first British battleship built without a ram on the prow, close combat having become so unlikely. The *Dreadnought* design had the effect of making capital ships of earlier design obsolete; the speed and concentrated, accurate, long-range firepower of a *Dreadnought* could overwhelm them.

However, the introduction of the class caused the British to suffer from the "law of unintended consequences." As an island nation with a far-flung empire, dependent on sea lines of communication, it had long maintained a policy that its fleet should exceed by 10% those of the next two largest navies combined. The introduction of this new class had leveled the playing field and caused a long-established advantage to be lost. Germany soon copied the *Dreadnought* design, and a naval arms race began—one of the major factors that combined to cause World War I. Britain could no longer afford its traditional naval advantage. Since the world's third largest Navy at the time belonged to the United States (not considered a threat), and since France was becoming an ally, Great Britain settled on a policy of maintaining 60% more capital ships than Germany. Maintaining even that advantage made other badly needed war preparations unaffordable. While it is unlikely that a new U.S. ship design will have similar consequences, this story reminds us to be alert for secondary effects.

> The Rapid Rise of Dominant Powers: In 1480, Spain was a collection of small kingdoms…Twenty years later Spain held title to half the globe. In 1850, Germany was little more than a geographic expression…By 1871, Germany was the dominant force in Europe.
> —*Operational Maneuver from the Sea*

ACCELERATING CHANGE

The 20th century has seen warship design evolve at an increasingly rapid pace. A few of the most significant have been:

- Long-range submarines
- Surface and airborne radar
- Naval aviation
- Effective and sophisticated mines and torpedoes
- Nuclear weapons
- Nuclear propulsion
- Guided missiles
- Gas turbine engines
- Computer-controlled systems
- Satellite surveillance and navigation
- Increasingly effective communication

We can expect technology development to continue to accelerate, resulting in an accelerating evolution of the methods of naval warfare.

THE CURRENT SITUATION

The 20th century has seen what could be viewed as another "hundred years war." Through most of the century there has been hot and cold war, most often pitting totalitarian states against democracies. The collapse of the Soviet Union has left the United States as the world's only superpower. Perhaps only during the *Pax Britannica* of the 1800s and the *Pax*

Romana of ancient times has one country had the power to influence the course of world events that the United States has today. Our current naval force structure was designed to contain the Soviet Union and, secondarily, to deal with "major regional contingencies." Today, contingencies such as Kosovo, Iraq, Somalia, and Haiti are a primary mission. The United States must also retain the flexibility to adjust to meet challenges from emerging powers. Clearly, ships with new capabilities and a different force structure will be required. As in the past, technology will be used to meet these challenges. We at Panama City and Dahlgren have, and will continue to develop, the technology that has such a major role in the design of this new Navy. The articles that follow illustrate this. As noted in *Operational Maneuver from the Sea*, our country's position in the world depends on how well we do this.

INTRODUCTION TO THE ARTICLES

In the first article, "**Tsunami-2050: A Naval Operational Concept and Force Design for the 21st Century**," one can gain insight into the origins of the requirements addressed by many of the subsequent articles. In it, O'Brasky and Anderson describe a vision of what U.S. maritime forces might become during the next half-century. The article describes a very mobile, network-centric force comprising low-signature manned and unmanned vehicles that will be capable of securing a hostile area before more traditional (and more visible) forces move in. The article contains many innovative ideas, including the full merger of the Navy and the Marine Corps. Whether or not it proves prophetic, this article highlights the issues the Navy will face.

The articles that follow O'Brasky and Anderson's fall into two broad categories. One category includes descriptions of new systems and capabilities including land attack, littoral operations, and command and control. The other category includes articles describing improved methods of attaining capabilities. It is clear that the Navy must "do more with less" in the future. Topics such as reduced manning, use of commercial equipment, and better architecture and design methods fall into this category.

> It was the unbeatable combination of surface and air power and scientific research that enabled the British and American antisubmarine forces to win (the battle of the North Atlantic).
> —*Samuel Eliot Morrison in*
> The Two Ocean War

NEW CAPABILITIES

Land Attack

The Kosovo crisis has highlighted the requirement for more effective land attack methods, both in precision and in volume of fires. For precision land attack today, the U.S. relies largely on highly effective, but expensive, cruise missiles and on guided bombs, whose delivery may put a pilot at risk. The ability to rapidly deliver relatively inexpensive, very precise, long-range munitions that complement these missiles and bombs will be a principal driver of the design of future surface combatants. Podlesny's article, "**Operational Employment Challenges Facing Naval Fires in the 21st Century**," describes potential tactical situations and explains the extraordinary requirements for fighting in the "urban terrain." It addresses requirements for command, control, and communications (C3); intelligence, surveillance, and reconnaissance (ISR); and precision delivery of ordnance.

An advanced gun system and upgrades to current guns will be major contributors to meeting land attack requirements. Advanced gun systems can be expected to have large magazines, a variety of munitions, and a rapid rate of fire; and they will fire precisely guided projectiles. The Global Positioning System (GPS) will be a key component of the guidance system. In the article "**Active Jamming Cancellation Concept for Extended Range Guided Munitions**," Wiles, Ohlmeyer, and others describe methods for effectively overcoming jamming of GPS input to the guidance system of extended range guided munitions now under development.

Aegis ships will make up the majority of the cruiser/destroyer fleet well into the next century. Upgrades to these ships will be required to meet evolving requirements. In "**A Common Land Attack Warfare System (CLAWS) for Aegis Combatants**," Weeks and Ball describe a system that will facilitate land attack. This article describes how the Aegis combat system will be upgraded with extended range guided munitions, new varieties of Tomahawk cruise missiles, and a supersonic land attack missile. This article summarizes a vision of a fully integrated CLAWS, which will enable a single set of operators to perform all land attack functions across both gun and missile systems. CLAWS is scheduled to first appear in Baseline 7 follow-on and will be backfit to earlier baselines.

No matter how accurate a weapon is, it cannot do its job unless the location of its target is known. During the Beirut crisis in 1983, it was discovered that *USS Ticonderoga* could track artillery shells with her AN/SPY-1A radar. In "**Naval Fires from the Sea for Supporting Littoral Operations: Counterbattery**," Houchins and Rivera describe a system currently being installed on Aegis ships that will permit the combat system to use such data to compute the location of artillery sites for counterbattery targeting. The article also addresses implementation of this capability in future surface combatants.

Operating in the Littoral Battlespace

The requirement to operate close to shore means that potential enemies may be operating nearby either undetected or unidentified. This makes self-defense issues even more pressing than when operating in the open ocean. In "**Naval Ship Self-Defense Weapon Littoral Warfighting Performance Issues**," Graff concludes, "The need to conduct naval operations in littoral seas results in a complex new set of ship defense challenges. These challenges include adverse propagation environments, and defeat of multiple small weapons launched from very short range." The article examines alternatives for improving ship self-defense.

Also important in littoral regions is self-defense against chemical and biological weapons. Ships in littorals can be more accurately targeted and have less room to maneuver for escape from such threats. In "**Future Surface Combatant Chemical and Biological Warfare Protection**," Driscoll and Fitzgerald describe required capabilities, such as collective protection systems, real-time hazard assessment, a full suite of chemical and biological warfare standoff and point detection systems, postattack monitoring systems, and self-decontamination capability—all of which must be operated at reduced manning levels. These systems must be highly automated and integrated with a joint warning and reporting network to obtain maximum benefit from the multitiered approach. They describe how all of these needs are being addressed through Naval Surface Warfare Center, Dahlgren Division (NSWCDD) leadership in both Navy-specific and joint service programs.

It could be effectively argued that the single technological development that has most affected 20th century naval warfare has been radar. Its development was greatly accelerated by World War II. In 1939, although some warships were equipped with primitive radar, *Graf Spee*, her quarries, and her pursuers located each other primarily by visually sighting smoke or masts. Technology developed so quickly that by 1942 U.S. superiority in radar was a key to turning the tide in the Pacific at the battles of Midway and Guadalcanal. The development of airborne microwave radar for antisubmarine warfare was an indispensable factor in the combination of methods that enabled the Allies to win the Battle of the North Atlantic. Without its contribution to suppress U-boat activity, it is unlikely that a timely invasion of Europe would have been feasible. Fire control radars soon greatly improved the accuracy of munitions. The development of the SPY-1 series of multifunction array radars made it feasible to operate battle groups in areas where they might face heavy cruise missile attacks. In "**Radio Detection and Ranging (RADAR)—Past, Present, and Future**," Giorgis and Sims review the past and predict the types of radar that may be carried by future combatants.

Tsunami-2050 envisions that a stealthy force, including unmanned vehicles, will be clearing hostile areas before more visible assets arrive. In

"**Unmanned Vehicles and the Tactical Control System for the DD 21**," Peterson describes how a control system for such vehicles might be implemented on DD 21. Such vehicles already exist in surface, subsurface, air, and ground varieties. They will be key to locating targets and identifying threats with minimal risk to human life.

Network Centricity

Tsunami-2050 describes a family of systems operating together in complete coordination. This coordination will require massive amounts of data processing and correlation. In "**C3I and Tactical Picture Compilation: Detect, Assess, Allocate, and Respond**," Luessen describes a method for processing a seemingly overwhelming amount of data from disparate sources into a coherent tactical picture for the command team. This article employs an author-developed Detect-Assess-Allocate-Respond sequence to describe and discuss the C3I process and the building of a coherent picture.

To be able to communicate, sense, and carry on all the functions of a combatant that require electronic emissions, it is essential to minimize interference. In "**Integrated Topside Design**," Stetson and Mearns address past and current problems with electromagnetic interference, and describe methods to overcome them on future ships. They describe a topside design process that includes frequency management, federated apertures, integrated antennas, and many other methods. A notional design that could be applied to DD 21 is presented.

Secure communications and access to secure information at the appropriate level are essential to military operations. In "**Multilevel Security Without Encryption**," Ratway explains that currently there is no multilevel security (MLS) system composed of heterogeneous networks and computers certified for operation in a ship environment. Most currently proposed solutions to this MLS problem rely on encryption. Encryption—the transformation of plain text into cipher, which usually has the appearance of random unintelligible data—is the second step in secure data transfers used to deny access to unwanted receivers. The first step is authentication of sender and receiver. This article offers a design for an MLS system without encryption; that is, a system that uses authentication only.

It is important that issues such as the above be considered early in any design process. The DD 21 will offer the first modern opportunity to perform total ship design of a destroyer/cruiser. The DD 963 hull was designed to accommodate a combat system that would be supplied later. That combat system has evolved steadily. For CG 47 class ships, the Aegis combat system was fit into a modification of that DD 963 hull. The DDG 51 hull was designed to accommodate the Aegis combat system. The DD 21 hull and combat system are being designed together, with the intention that the hull will later accommodate the CG 21 combat system with expanded antiair warfare capability.

> We will need organizations and processes that are agile enough to exploit emerging technologies and respond to diverse threats and enemy capabilities.
> —*Joint Vision 2010*

NEW METHODOLOGIES

The articles cited above describe a few of the many new capabilities the Navy must field in the next century. An equally important factor requiring new approaches is the constrained fiscal environment and the opportunities presented by new technologies. Costs of building, crewing, operating, and maintaining surface combatants over their full life cycle must be significantly reduced if the Navy is to build and sustain a fleet of sufficient size to meet this country's requirements within a realistic budget. In order to achieve this goal, ships must be engineered as total systems (and as part of a total military system, including joint and coalition forces). Cost containment will be achieved by many techniques, including drastic cuts in personnel, improved maintainability, improved planning of logistics, use of commercial off-the-shelf (COTS) equipment, use of advanced computing technology, and improved acquisition policies, including simulation-based acquisition.

Total Ship Design

In "**Total Ship Systems Engineering**," Horner describes a methodology that addresses the need for a framework for systems engineering of Navy ships. This article proposes a process for developing cost-effective systems using acquisition reform principles. This will require a great amount of systems analysis using modeling, simulation, and prototyping. The methodology supports a continuous process of refining ship systems requirements. The article describes future engineering development environments that provide an integrating framework of tools and methods to support analysis, design, and trade studies. Several of these methods are already appearing in emerging ship design techniques. Examples include the use of integrated data environments and smart product models in LPD 17 and DD 21 design processes.

"**Combat System Architecture**," also by Horner, describes another aspect of the ship design process. It characterizes the need to partition system components with like functions into groups with well-defined and, when possible, standard interfaces. This facilitates support by a common infrastructure and is a departure from traditional partitions into warfare areas. One of the more important partitions is isolation of data communications and storage management from other systems' components and processes. The need for more advanced control models that support the integration of human and machine resources is identified. Successful application of this architecture can be expected to enable both control of system life-cycle costs and achievement of integrated warfighting solutions.

Improved Efficiency

The theme of efficiency recurs throughout this *Technical Digest*. Crew size does much to determine the lifetime cost of operations of a class of ships. In "**Optimized Crews for the 21st Century**," Hamburger, Bost, and McKneely address this issue. They point out that the U.S. Navy has set ambitious crewing goals for new surface ships, including a goal of 95 people for DD 21. Future ships must also possess both the operational flexibility to meet the requirements of littoral and open-ocean environments, and a nearly "puncture proof" self-defense capability. To reach these goals, it is argued that systems engineering teams must apply human systems integration and advanced technology within the total ship systems engineering process. This approach will produce a ship design that approaches optimal crewing within cost and performance constraints while maximizing ship and system effectiveness, readiness, reliability, total performance, and safety. The article describes both technical and cultural challenges that must be met by the Navy.

Reduced crewing necessarily means increasing automation. Holden addresses this issue in "**Controlling the Controller: The Unrelenting Challenge in Digital Shipboard Automation**." The article describes the gradual introduction of automation into surface combatants and its (still largely unrealized) potential to reduce crewing requirements. The article describes how control of the automating element emerged as the central issue when control of machinery was transferred from watchstanders to computers. Issues attached to the increasing use of COTS computers and software are addressed, including the need for a responsible certification authority. (It is expected that Dahlgren has been assigned that role for DD-21 software.)

In "**Rehosting the Aegis Embedded Trainer in Commercial Products**," Miller and Lipe describe how the Aegis Combat Training System—a legacy trainer with embedded computers—was modified to incorporate numerous COTS items. The article shows how the transition from a MIL-SPEC environment (including high-order language, real-time operating system, compilers and linkers, target computing system, and interfaces) to an all COTS environment was successfully achieved within a 3-year period. The methodology they describe can serve as a reusable blueprint for COTS introduction into legacy systems.

The use of distributed computing plants and multipurpose consoles will require the ability to rapidly reconfigure computers and other equipment. In "**The Role of Switching in Engineering Surface Combatants of the Future**," Francis and Gorder tell us that fast and reliable switching is an integral part of research, development, testing, and engineering of surface combatants. This article describes the utility of switching at combat system shore sites and reviews the value of switching in the combat system engineering process. The authors discuss the required and desired properties of a suitable combat system switch, including speed; overall capacity; ability to handle multiple data transfer formats; and reliability, maintainability, and availability issues. Finally, the article reviews the recent development of the Aegis switching/data transfer system and considers possible future military and commercial applications of advanced switching technology.

SUMMARY

The articles in this issue illustrate the great breadth and depth of the capabilities of the Panama City and Dahlgren laboratories. They document work that ranges from total fleet design concepts to mission and operational environment analysis, and from functional analysis to technology development. Each of the efforts described herein is helping to ensure that the U.S. Navy retains a decisive lead in naval warfare, especially those capabilities supplied by surface combatants.

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THE GUEST EDITOR

DR. JOHN L. BAILEY

Dr. John L. Bailey is a senior scientist in the Surface Ship and Combat Systems Division, Combat Systems Department. He is a graduate of the Massachusetts Institute of Technology (S.B., math, 1964), University of Tennessee (Ph.D., math, 1968), and Virginia Polytechnic Institute and State University (M.S., computer science, 1975). He was an Assistant Professor of Mathematics at the University of Tennessee before accepting a position with NSWCDD, Dahlgren in 1969. He has worked as an analyst and in modeling and simulation applied to minefield planning and evaluation, ship survivability, Aegis, and currently, theater ballistic missile defense and the 21st century destroyer. He served as Science Advisor to Commander, Mine Warfare Command during 1978 and 1979, in an additional duty assignment as Modeling and Simulation Coordinator for the Aegis Program Office (PMS 400), 1981-1988, and as the Combat System Department representative to the Dahlgren Division Modeling and Simulation Focus Team since 1992 . He has published in refereed mathematics journals, in the *American Society of Naval Engineers Journal*, and in laboratory technical notes and reports.